Glider-based Passive Acoustic Monitoring Techniques in the Southern California Region & West Coast Naval Training Range Demonstration of Glider-based Passive Acoustic Monitoring

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LONG-TERM GOALS

The long-term goals are to develop and improve glider-based and autonomous-platform-based marine mammal monitoring for Navy environmental compliance, as well as for basic scientific studies of marine mammals. Autonomous glider-based passive acoustic monitoring of marine mammal presence is particularly needed within the southern California offshore region, a site of significant naval training. We aim to create operational glider-based marine mammal detection, classification, and localization systems to provide timely information on marine mammal presence to support Navy mitigation efforts in the southern California region. An important aspect to achieving these goals is quantitative evaluation of the monitoring capabilities of passive acoustic systems, and separation of calling behavior from the effects of the environment.

OBJECTIVES

Our objective is to develop and test glider and autonomous-platform-based capabilities for marine mammal call detection, classification, and localization (DCL). Because of their long-duration on-station time and acoustically silent operation, gliders provide attractive platforms for acoustic monitoring over extended periods of time, with significant processing capabilities for detection, classification and localization of marine mammal calls. For gliders to be effective in this role, efficient algorithms for automated detection, classification, and localization of marine mammal calls are needed. In addition, we have been testing various autonomous platforms (submerged versus surface) for marine mammal call passive acoustic monitoring capabilities, and comparing these platforms against fixed bottom-mounted acoustic sensors. These monitoring capabilities are being evaluated using a combination of at-sea data analysis results and numerical modeling with full wave-field acoustic propagation codes.

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APPROACH

We are exploring two mobile, autonomous platforms with capabilities for real-time, persistent, passive acoustic monitoring: the flying wing ZRay autonomous underwater glider and the Wave Glider autonomous surface vehicle. ZRay is the world's largest underwater glider, employing a high lift-to-drag ratio wing design allowing efficient long distance travel at higher speeds and with order-of-magnitude greater payload carrying capability than traditional profiling gliders. The Wave Glider, manufactured by Liquid Robotics, has a surface float connected by cable to a submerged glider, which uses wave action for forward propulsion. The continuous presence at the ocean surface of the Wave Glider float, which includes satellite-based data communications, allows for continuous, instantaneous notification of marine mammal calling activity. The passive acoustic monitoring performance of these mobile autonomous platforms are being compared with fixed, bottom-mounted autonomous systems including the Navy range hydrophones and the High-frequency Acoustic Recording Package (HARP) wide-band system.

We have formed a collaborative team to investigate the ZRay and Wave Glider capabilities for marine mammal monitoring. Gerald D'Spain is responsible for ZRay glider development and integration of marine mammal DCL capabilities. John Hildebrand and Sean Wiggins are responsible for Wave Glider-based development of marine mammal recording and detection/classification hardware and software. Marie Roch of San Diego State University has been assisting in the development of hardware and algorithms for real-time marine mammal detection and classification. This effort benefits from partnership with Mark Stevenson and Wayne Husband at SPAWAR Systems Center, Pacific and is heavily leveraged with other ongoing projects.

WORK COMPLETED

The work completed this past year falls into four categories. First, the algorithms developed in this program for near-optimal detection and localization of transient signals continued to be improved and expanded to work with a variety of marine mammal species, both in near-real time and in post-processing, and with transient signals in other applications. Algorithm refinement has been aided by the data collected on ZRay by both its leading edge hydrophone array and the SPAWAR SSC Pacific 16-element towed hydrophone array during the October, 2011 and November, 2011 glider engineering sea tests. The near-optimal Generalized Power-Law (GPL) detector, which uses an exponent for the Fourier amplitudes that is 2 to 3 times greater than that of an energy detector, has been integrated into the standard processing string for two large passive acoustic data sets; one collected in the eastern Pacific Ocean as part of Navy range monitoring and one collected during open water season in the Arctic by the oil and gas industry. The optimal transient localization algorithm was further developed and applied to the ZRay array data sets, and to additional data from both hydrophone arrays and acoustic vector sensors.

A second research thrust has been in quantitative evaluation of the passive acoustic monitoring capability of mobile and fixed sensors. The basis for this evaluation is the estimated probability of detection as a function of time over a given monitoring area, allowing passive recordings to be calibrated for environmental effects. As described in Helble et al., 2012b, estimating this probability of detection involves extensive acoustic field propagation modeling combined with analyses of the recorded data.

A third major focus this year has been to publish the results of the research. One paper (Helble et al., 2012a) was published, a second paper on estimating the passive acoustic probability of detection (Helble et al., 2012b) was submitted for the special issue of the Journal of the Acoustical Society of America (JASA) on Methods for Marine Mammal Passive Acoustics, and a third paper on the importance of calibrating passive monitoring data for environmental effects (Helble et al., 2012c) was just submitted to JASA Express Letters.

A fourth effort has been to prepare for the November, 2012 southern California Navy range monitoring exercise. This test will involve both the ZRay flying wing autonomous underwater glider and a Wave Glider (Figure 1). The passive acoustic monitoring systems on the ZRay glider will include the 27-hydrophone array along the leading edge of the glider, a three-channel (two mid-frequency channels and one low-frequency channel) digital acoustic monitoring (DMON) system developed by the Woods Hole Oceanographic Institution, and a 32-element, 25-m-long, towed hydrophone array designed and built by SPAWAR Systems Center (SSC) Pacific. The Wave Glider will tow a "mini-HARP", a wide-band hydrophone cabled to a long-duration data recording/processing system miniaturized for deployment on autonomous mobile platforms. Both ZRay and the Wave Glider will operate near a standard bottom-mounted, wide-band hydrophone recording package (HARP) presently deployed in the southern California (SoCal) Bight as part of the Navy's SoCal range monitoring effort. The recordings from all passive acoustic systems will be post-processed in an identical way so that their monitoring results can be quantitatively compared.

Figure 1. The ZRay flying wing autonomous underwater glider resting on its launch and recovery cart (left picture) and the Wave Glider (right picture). Both photographs were taken on the fantail of the R/V Sproul during the January, 2011 Range Validation Test on the Navy's Southern California Acoustic Range (SOAR).

Preparations for this multi-platform monitoring test have included applying for, and obtaining, an export license from the U.S. Department of State for the DMON system, preparing and submitting all necessary environmental paperwork, preparing a test plan, and coordinating the participation of the ZRay and Wave Glider research groups at the Marine Physical Lab/Scripps Institution of Oceanography, and the towed array/Wave Glider engineers at the SPAWAR SSC Pacific.

RESULTS

Passive acoustic monitoring results must be calibrated for environmental effects before any information on marine mammal calling behavior can be extracted. The importance of this calibration is illustrated by the following example taken from Helble et al., 2012c.

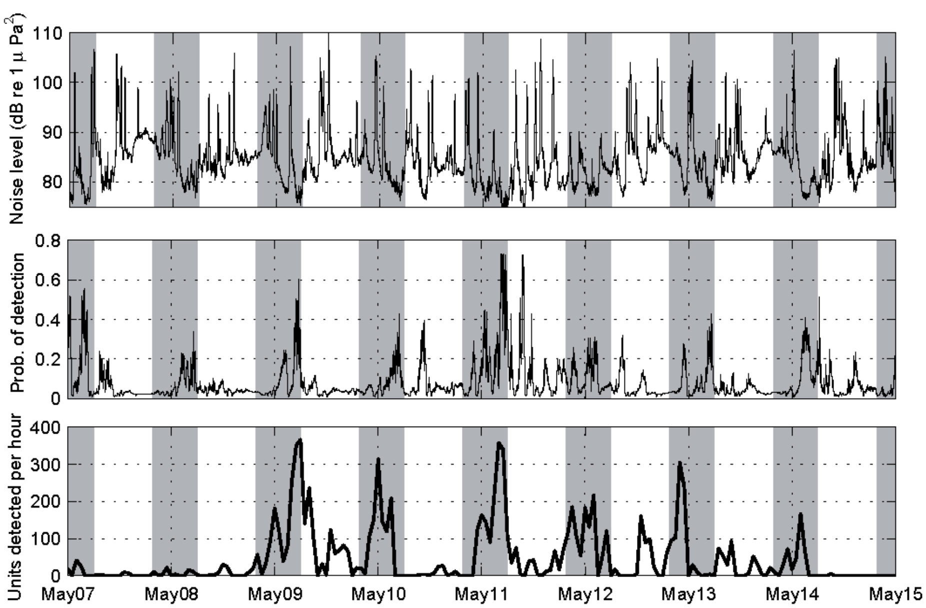

Figure 2. The ocean noise levels integrated over the 150-1800 Hz band recorded at the Santa Barbara Channel HARP site during a 1-week period in May, 2008 (upper), the numerically-estimated probability of detecting a humpback call unit within a 20 km radius of this HARP site (middle), and the number of uncorrected humpback call units detected per hour in the HARP data over this same 1-week period (lower). Shaded time periods indicate sunset to sunrise, with vertical grid lines marking midnight local time.

Figure 2 above shows data obtained from a HARP passive acoustic monitoring package deployed in the Santa Barbara Channel for a one week period in May, 2008. Examination of the lower plot by itself of the number of detected humpback calls in the HARP data over time appears to indicate a strong diurnal cycle to the calling activity, with significantly more calls occurring during nighttime. However, the middle plot, showing the estimated probability of detection over time, displays a significant diurnal cycle in the likelihood of detecting humpback units. This plot is obtained by numerically simulating the propagation of humpback calls from randomly chosen locations in the 20-km-radius monitoring area using a full wave-field acoustic propagation code, adding noise realizations recorded by the HARP, and then processing the resulting time series with the GPL processor (Helble et al., 2012b), just as is done with the recorded HARP data to obtain the lower plot. The temporal changes in the probability of detection account for most of the diurnal signal found in the humpback calling pattern for this period. While nearby transiting ships create large, short duration spikes in the upper noise plot, these spikes have little effect on the middle plot because the probability of detection already is low in the high noise daytime environment. In contrast, small noise variations around levels of 80 dB re 1 μPa^2 and below - levels which occur almost exclusively at night - have a significant effect on the middle plot. Specifically, when the ocean noise levels at this site decrease from 80 dB to 75 dB re 1 μPa^2, the probability of detection increases from 0.1 to 0.65. The importance of accounting

for variations in noise during low-noise conditions is due to the properties of signal propagation at this site, associated mostly with the basin shaped bathymetry. Results at other monitoring sites show varying sensitivity to changes in noise (Helble et al., 2012b). These results suggest that the spatial and temporal variability in the signal propagation characteristics and the ocean noise are important to take into account when interpreting passive acoustic monitoring results.

IMPACT/APPLICATIONS

This program has demonstrated the ability of autonomous gliders and platforms, properly equipped with passive acoustic sensor systems and detection, classification, and localization algorithms, to monitor marine mammal calls in near real time. Gliders provide ideal platforms for marine mammal acoustic studies owing to their persistence, silent operation, and non-disruptive presence. These systems may play a significant role in future passive acoustic monitoring related to Navy environmental compliance and mitigation associated with Navy exercises. The importance of accounting for spatial and temporal variability in environmental properties when interpreting passive monitoring results has wide-spread implications for the Navy's environmental monitoring efforts.

RELATED PROJECTS

Project title: Southern California Marine Mammal Studies; John Hildebrand, Principal Investigator. Sponsor: CNO N45 and the Naval Postgraduate School; Support from this project allowed for development of the HARP and comparison of glider and HARP data.

Project title: Flying wing underwater glider for persistent surveillance missions, Gerald L. D'Spain, Principal Investigator. ONR Grant: N00014-10-1-0045. This project supported development of large autonomous underwater gliders based on the flying wing design.

Project title: Passive acoustic monitoring for the detection and identification of marine mammals; Marie A. Roch, Principal Investigator. ONR Grant: N00014-08-1-1199. This project aided in the development of algorithms for marine mammal detection and classification.

PUBLICATIONS

Helble, T. A., G. R. Ierley, G. L. D'Spain, M. A. Roch, and J. A. Hildebrand (2012a). A generalized power-law detection algorithm for humpback whale vocalizations. *J. Acous. Soc. Am.* 131(4), 2682-2699.

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